TCC III, Motored, Full View

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Acknowledgement Request for published use:

It is requested that ALL published use of the TCC engine simulation geometry and/or data be acknowledged with the following statement.

> “The study here used publicly available TCC engine data, which was created with funding by General Motors through the General Motors University of Michigan Automotive Cooperative Research Laboratory, Engine Systems Division.”

This README document is an overview of the cataloged data in the Deep Blue Data work deposit “TCC-III, Motored, Full View”, which is a permanent unaltered archive of the data used in Dr. Philipp Schiffmann’s PH. D. dissertation (http://hdl.handle.net/2027.42/137636) and subsequent publications, such as Philipp Schiffmann, David L. Reuss, Volker Sick, International Journal of Engine Research, 2017, DOI: 10.1177/1468087417720558.

This document includes descriptions of the following.

Measured parameter locations and nomenclature are provided in the Geometry slides.

The Deep Blue Data TCC-III “Collection README.pdf” file contains references and errata, and will be updated in time.

TCC-III Motored Full-View Test Conditions & File Summary									
RPM	**MAP** kPa	**Image Plane**	**Grid**	**Recorded Pressure** cycles/test	**Imaged** cycles/test	**Recorded Images** imgs/test	**Image Range** deg. ATDCE	**Crankangles between images**	**Data ID**
800	**95**	y =0	PIV	300	235	142	0 - 705	5	**S_2014_05_20_02**
		z = -5	PIV	500	286	142	0 - 705	5	**S_2014_05_13_03**
		z = -30	PIV	1400	1157	50	55 - 300	5	**S_2014_04_17_02**
				reco					
1300	**95**	y =0	PIV	300	235	142	0 - 705	5	**S_2014_05_20_01**
		z = -5	PIV	500	407	142	0 - 705	5	**S_2014_05_13_02**
		z = -30	PIV	1400	1157	50	55 - 300	5	**S_2014_04_17_01**
1300	**40**	x =0	PIV & Com	300	235	142	0 - 705	5	S_2014_01_30_01
			PIV & Com	300	235	142	0 - 705	5	S_2014_02_04_01
			PIV & Com	300	235	142	0 - 705	5	**S_2014_02_05_02**
		y =0	PIV & Com	300	240	139	0 - 690	5	**S_2013_10_24_01**
			PIV & Com	300	240	139	0 - 690	5	S_2013_11_07_02
			PIV & Com	300	116	286	0 - 712.5	2.5	S_2013_11_11_01
			PIV	3569	3035	11	40 - 100 180 - 300	10 40	S_2014_05_20_03
		z = -5	PIV & Com	500	407	142	0 -705	5	**S_2014_05_05_01**
			PIV & Com	500	407	142	0 -705	5	S_2014_05_05_02
			PIV & Com	500	407	142	0 -705	5	S_2014_05_07_01
		z = -30	PIV	1200	1134	49	55 - 300	5	S_2014_03_26_01
			PIV	1200	1157	49	55 - 300	5	S_2014_04_03_01
			PIV	1400	1157	49	55 - 300	5	**S_2014_04_16_02**

RPM – Revolutions Per Minute,
MAP – Manifold Absolute Pressure
ATDCE – degrees After Top Dead Center Exhaust, all data use this crank angle convention.
Data ID – File name used in archive directory, indicating data taken S_year_month_day_test#
Files in **blue-bold** font indicate recommendations from Schiffmann's PhD dissertation.

Motored Full View: Data Summary and File Structure

Slides 3 – 10 summarize the archive data-file directory structure, which contains pressure and velocity measurements acquired at multiple crank angles, during hundreds of contiguously engine cycles, at each engine-operating condition. There is one complete data set cataloged by **Test ID (bottom, Slide 2)** at each of the particle image velocimetry, **PIV, measurement planes (Slide 4)**.

Pressure data for each test is cataloged in Excel Workbooks, which contain worksheets with the following parameters.

Test Info	(pressure-data cycle number vs. imaged-data cycle numbers)
Per_Run_Summary	(test average & standard deviation)
Per_Cycle_Data	(cycle averaged parameters)
Ensemble_Average	(cylinder volume and average pressures per crank angle)
P_IntakePlenIn (kPa)	(5 **measured pressures (Slide 5)** acquired each 0.5 crank angle degree)
P_IntkPort (kPa)	.
P_Cyl (kPa)	.
P_ExhPort (kPa)	.
P_ExhPlenOut (kPa)	

There is one Pressure file for each test, located in the **Pressure Data-File Directories (Slide 6)**. The Pressure files include parameters that were directly measured or computed as described in **Schiffmann's Dissertation (**http://hdl.handle.net/2027.42/137636**).**

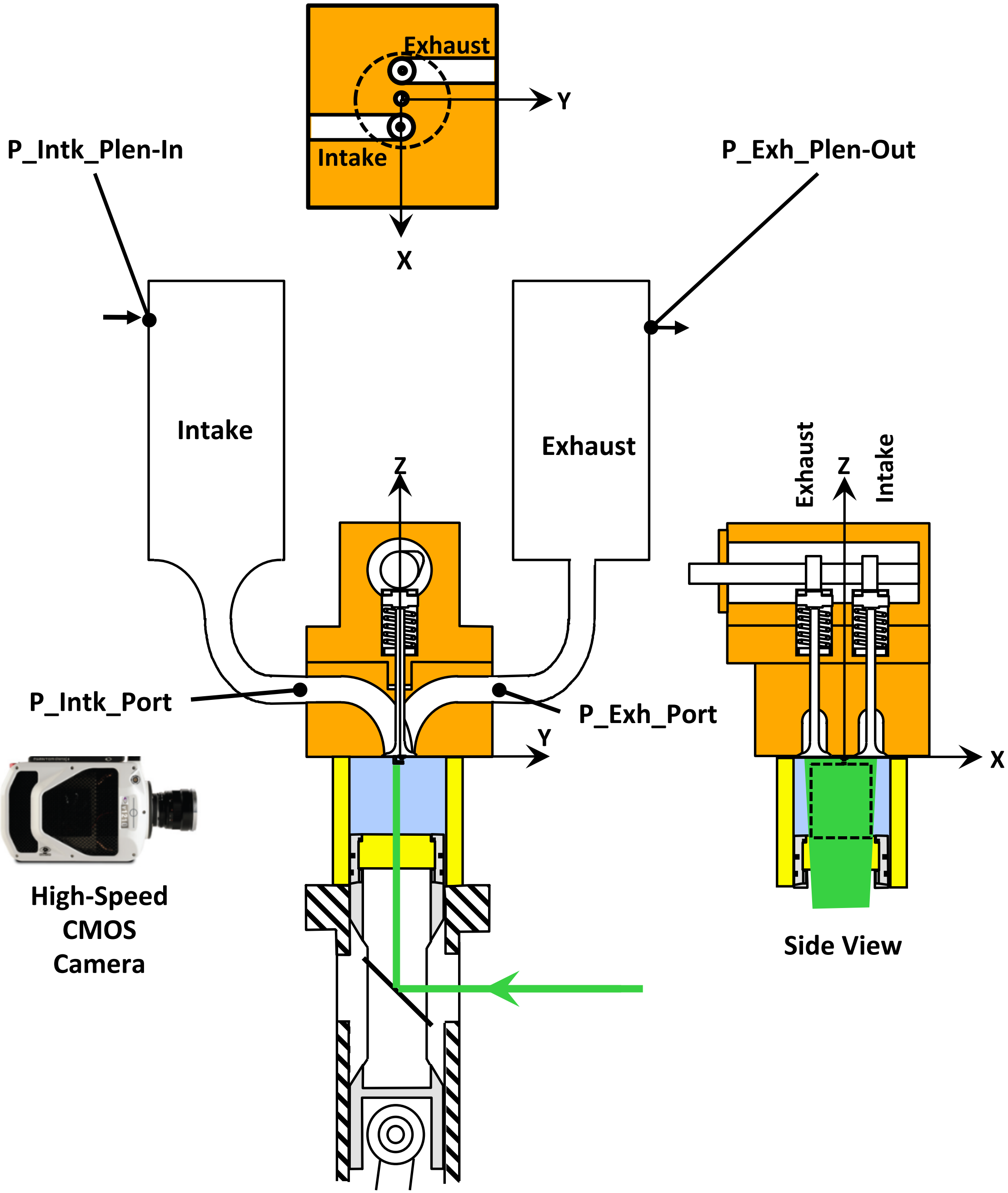
Velocity data are in text files, B000##.txt, containing the x,y,z coordinates and u,v,w velocity components of the two-component, **PIV measurement planes (Slide 4).** Each velocity file contains the velocity distribution from one image pair, taken with frame straddling. Thus, one image was taken at the beginning of the specified crank angle, and one was take Δt μs earlier (laser pulse separation), at the end of the previous crank angle.

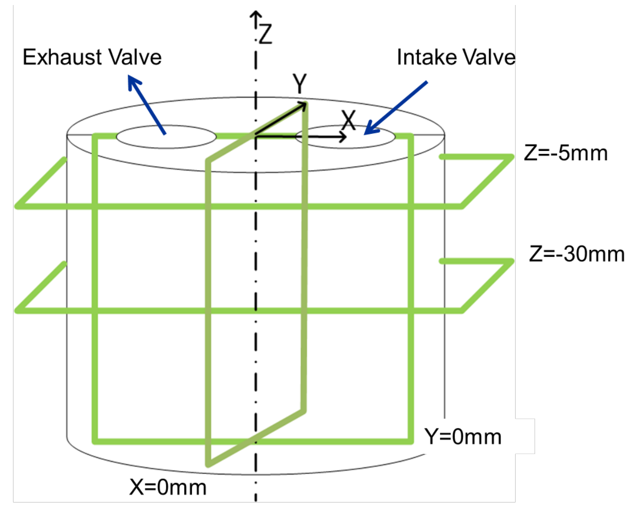
The velocity data are located in the **PIV Data-File Directories (Slide 7),** cataloged by

Test ID,	S_year_month_day_test#, e.g., S_2013_01_30_01.
PIV measurement plane,	e.g., x=0 as shown in Slide 4.
Test cycle number,	Cycle=000##
Crank angle,	B000## = crank angle ATDC, values found in **Vector_field_encoder.xls (cf. Slide 7)**

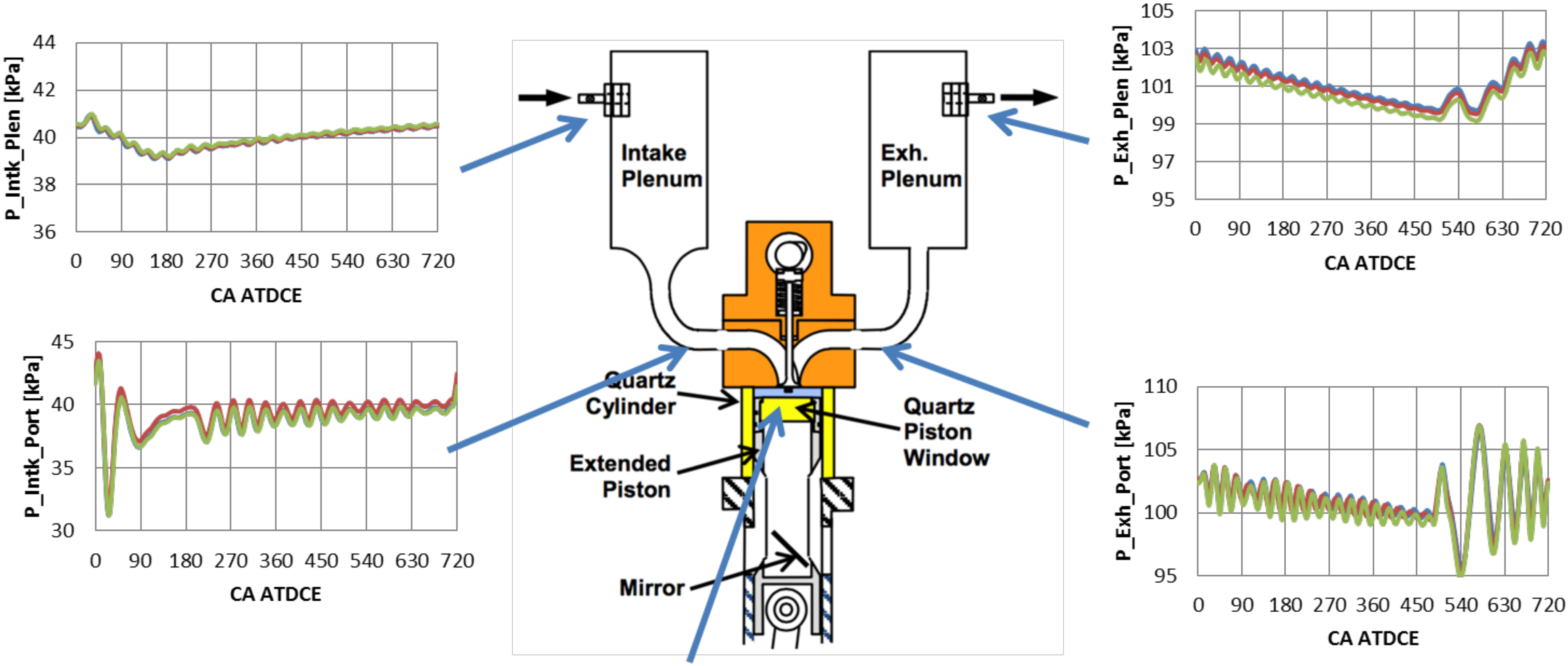
The velocity distribution are provided on the **Original Grids and a Common Grid (Slide 8)** with the **Resolution and Dynamic Range (Slide 9)**.

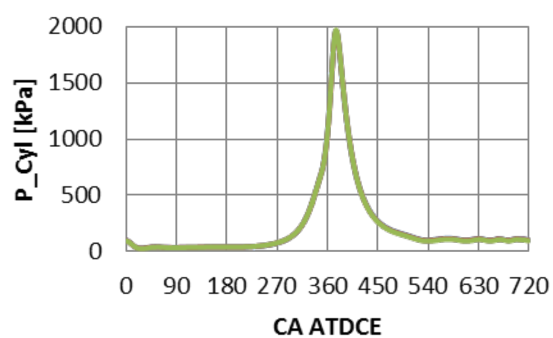
Coordinate system and image-plane labels used in file structure





Pressure Measurement Locations, TCC-III

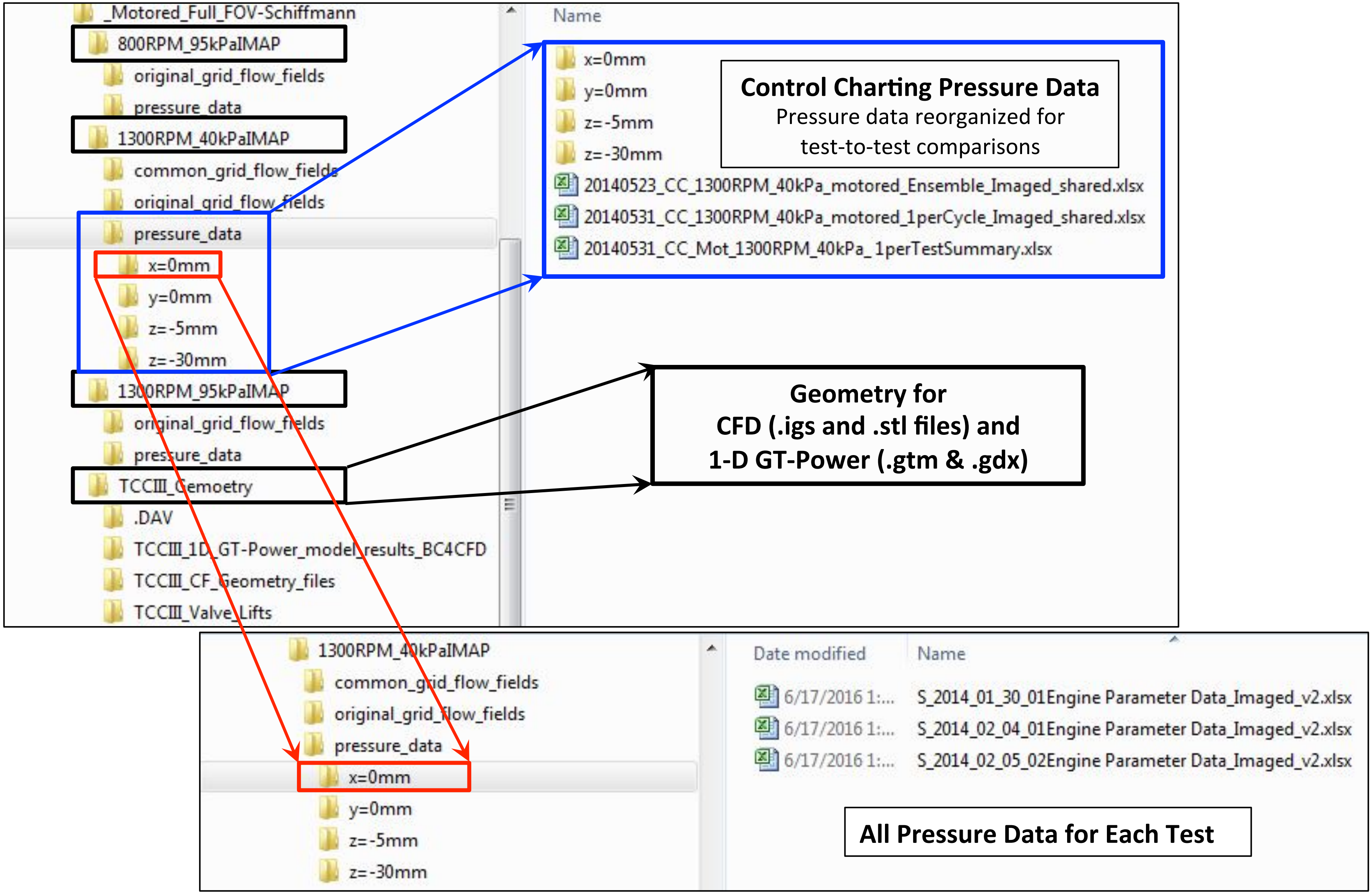




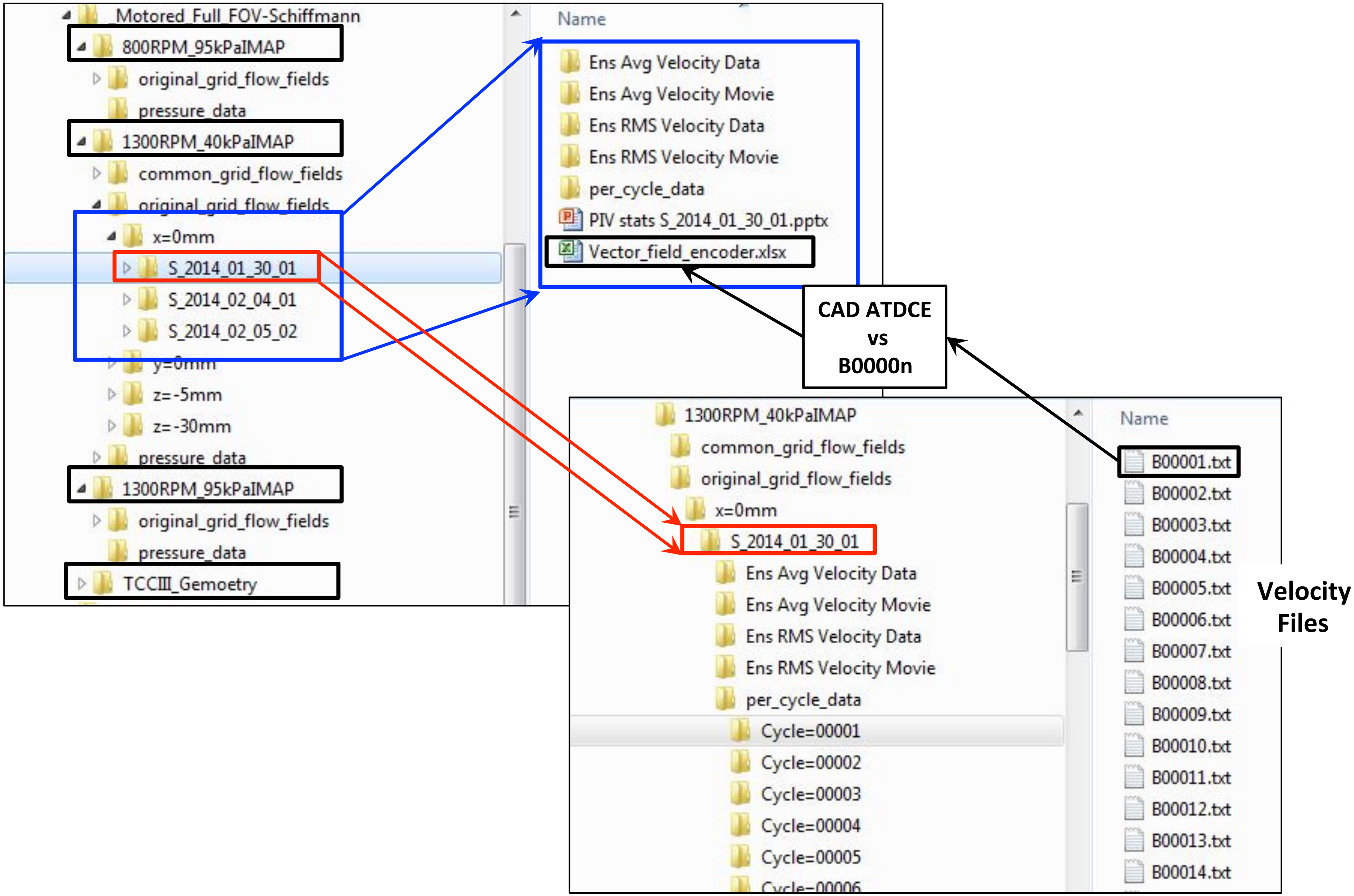
All Pressures posted for all tests, all cycles, all CA.

1/test, 1/cycle, 1/CA parameters for each tests are cataloged in Microsoft Excel files.

Motored Full View: Pressure Data-File Directory Structure



Motored Full View: PIV Data-File Directory Structure



Motored Full View: PIV FOV & Spatial Resolution

Original Grid:

The field of view (FOV) is restricted by the piston window to approximately the center 60-70mm for both vertical and horizontal measurement planes. In both the z=-5mm and z=-30mm planes the light sheet is brought into the cylinder from the positive x-direction. Thus, during intake stroke a major part of the FOV is blocked by the intake valve and its shade for the z=-5mm images. The vertical cutting planes have a FOV from piston to cylinder head with an approximate width of just below 70mm. The spatial resolution is 2.0 – 2.4mm with a vector spacing of 1 - 1.2mm.

Videos of the ensemble average flow field and ensemble RMS velocities can be found in each dataset folder, together with ensemble average data, as well as cycle resolved velocity data.

Common Grid:

For some datasets both the original PIV grid and a re-gridded version of the data is available, which was used by the author to compare flow fields of different tests and conditions. All vectors were interpolated on a common grid, of about the original grid size using a linear interpolation.

The re-gridded datasets loose one grid at edge of the FOV. The re-gridded data sets also use interpolation to fill locally bad vectors.

Motored Full View: Velocity Resolution and Dynamic Range

The minimum and maximum resolved velocity are defined here using the criterion that PIV correlation-peak displacements, Δx_{piv} , need be limited to 0.2 pixels and 8 pixels, respectively, as described in Ref.1. A practical resolution limit of 0.2 pixels is used here, as demonstrated in Refs.2 & 3. Thus, an estimated dynamic range of 40:1 is achieved. The laser-pulse separation, Δt, was changed throughout the cycle as described in Ref. 4, to assure that three standard deviations of the velocity distribution was 8 pixels or less. For measurement planes x=0 and y=0, within and during the intake jet, 12 pixels were allowed to better capture the lower speed flows away from the jet; this is justified by the fact that most of the jet flow is in plane for x=0 and y=0, and recursive and adaptive interrogation windows were used to capture the large velocities. Some data sets catalogued here have a file called "PIV Stats" to show the range of velocities and number of first choice vectors throughout the cycle. These plots were used to determine the Δt needed at each measurement plane for each crank angle. The velocity dynamic range for any data set can be computed as follows. Since 32x32pixel interrogation windows and grid-spacing, Δx_{grid}, of 50% overlap are used in all tests here, the resolution dynamic range can be estimated as

$$V_{min} = 0.2[2\Delta x_{grid} /32\Delta t] \quad \text{and} \quad V_{max} = 8[2\Delta x_{grid} /32\Delta t],$$

w Δx_{grid} is in meters (from the velocity data file) and Δt in seconds from the tables below.

1300RPM40kPa motored Dt x=0mm		
CA Range (° ATDCc)		dt (µs)
-360	-355	50
-350	-350	30
-345	-335	20
-330	-330	15
-325	-320	6
-315	-310	5
-305	-300	4
-295	-230	5
-225	-215	10
-210	-200	15
-195	-180	20
-175	-165	25
-160	-5	30
0	15	35
20	25	50
30	30	60
35	40	75
45	120	80
125	125	60
130	130	30
135	135	15
140	145	10
150	150	8
155	210	5
215	225	10
230	245	15
250	330	20
335	345	25

1300RPM40kPa motored Dt y=0mm		
CA Range (° ATDCc)		dt (µs)
-360	-350	100
-349	-335	60
-334	-330	40
-329	-320	10
-319	-310	5
-309	-300	4
-299	-225	5
-224	-200	15
-199	-180	20
-179	-165	25
-164	-30	30
-29	-20	40
-19	-5	50
-4	130	80
131	135	30
136	145	20
146	155	12
156	195	6
196	200	8
201	215	10
216	225	15
226	250	20
251	330	25
331	350	40
351	357	60

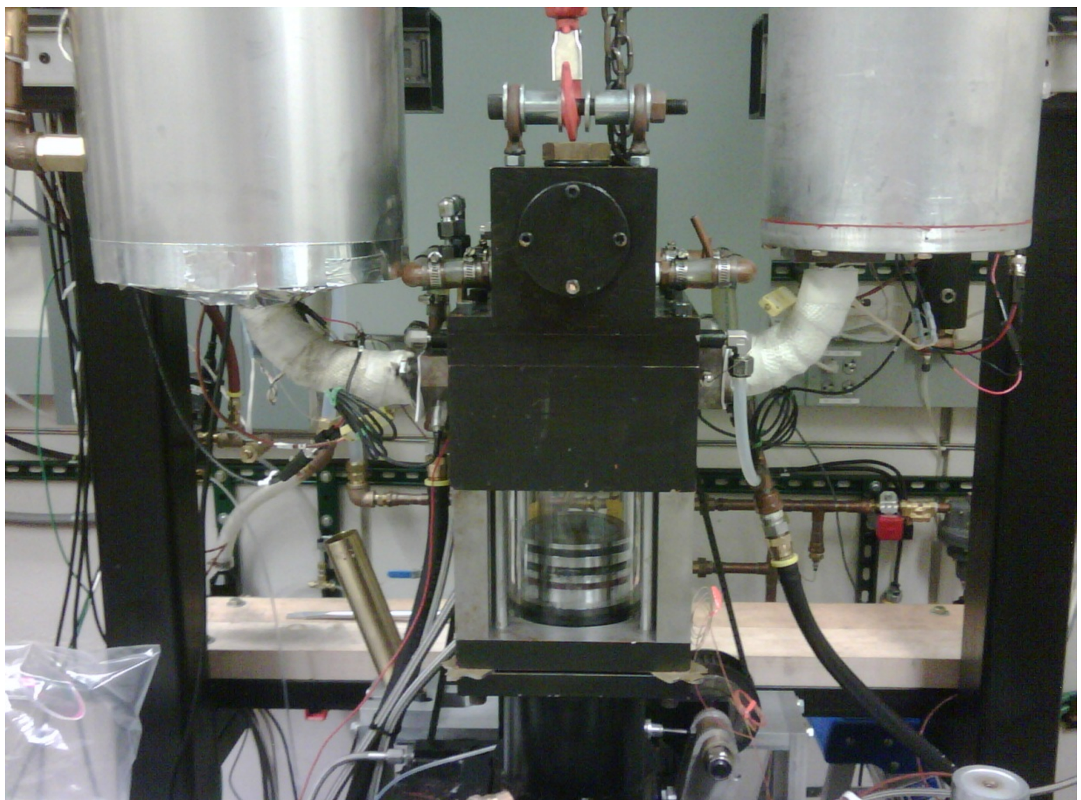
1300RPM40kPa motored Dt z=-5mm		
CA Range (° ATDCc)		dt (µs)
-360	-350	20
-345	-335	10
-330	-330	5
-325	-325	4
-320	-295	3
-290	-190	4.5
-185	-180	7
-175	-165	10
-160	-125	20
-120	-55	25
-50	-5	20
0	5	25
10	10	30
15	100	40
105	120	30
125	125	18
130	130	10
135	150	5
155	210	3
215	245	5
250	255	6
260	275	8
280	310	10
315	345	15

1. Adrian, R.J. and J. Westerweel, Particle image velocimetry. 2011: Cambridge University Press.
2. Reuss, D.L., M. Megerle, and V. Sick, Particle-image velocimetry Measurement Errors when Imaging through a Transparent Engine Cylinder. Measurement Science and Technology, 2002.
3. Megerle, M., V. Sick, and D.L. Reuss, Measurement of Digital PIV Precision using Electrooptically-Created Particle-Image Displacements. Measurement Science and Technology, 2002. 13: p. 997-1005.
4. Abraham, P.S., D.L. Reuss, and V. Sick. High-speed particle image velocimetry study of in-cylinder flows with improved dynamic range. in SAE Paper 2013-01-0542. 2013

TCC-III Engine Geometry

The Slides 10 – 24 quantify the TCC-III engine geometry, that was used to create the CFD .stl and igs files. In addition, these geometry slides define the nomenclature and locations of the pressure transducers and thermocouples cataloged in the Pressure Data Files.

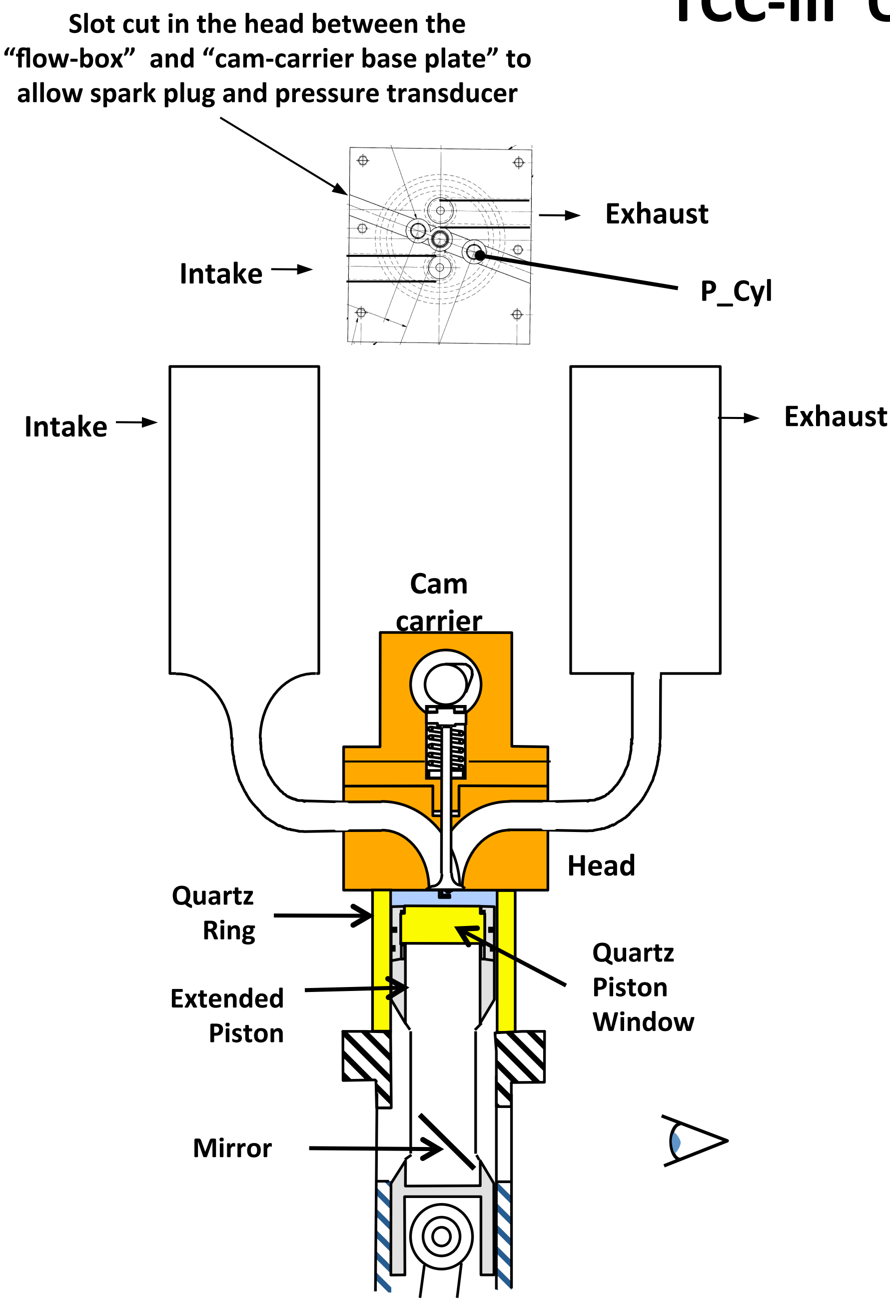
Scanned figures of original printed material are used to avoid transposition errors. The Deep Blue Data TCC-III Collection README file contains errata, which are updated as they become available.

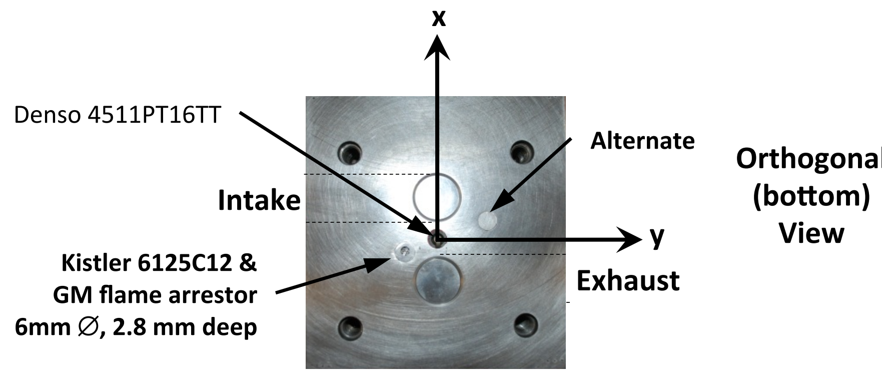


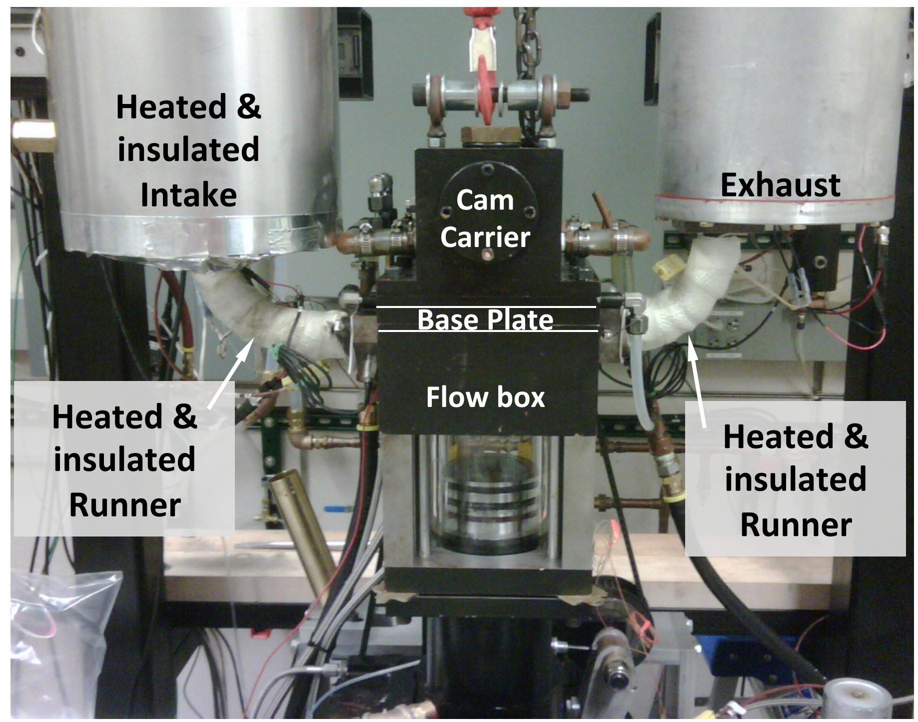
TCC-III Engine Geometry			
Bore, cm	9.20	Connecting-rod length, cm	23.1
Stroke, cm	8.60	Piston-pin offset, cm	0.0
Clearance @ TDC, cm	0.95	Conn rod offset, cm	0.0
Combustion chamber volume, cc	63.15	Exhaust Valve Closing, aTDCexh	12.8
Top-land crevice volume, cc	0.37	Intake Peak Lift, aTDCexh	114.8
Spark-plug crevice volume, cc	0.02	Intake Valve Closing, aTDCexh	240.8
TDC Volume, cc	63.54	Exhaust Valve Opening, aTDCexh	484.8
Swept volume, cc	571.7	Exhaust Peak Lift, aTDCexh	606.8
Geometric CR	10.0	Intake Valve Opening, aTDCexh	712.8
Effective (IVC) CR	8.0	Valve-seat angles, deg.	30/45/60/75
Steady-flow swirl ratio	0.4	Spark Plug	AC Delco R44LTS

TCC-III Overview

The three-piece head
"cam carrier" (cam and lifters)
"base plate" (valves & guides)
"flow box" (ports, plug, valve seats)

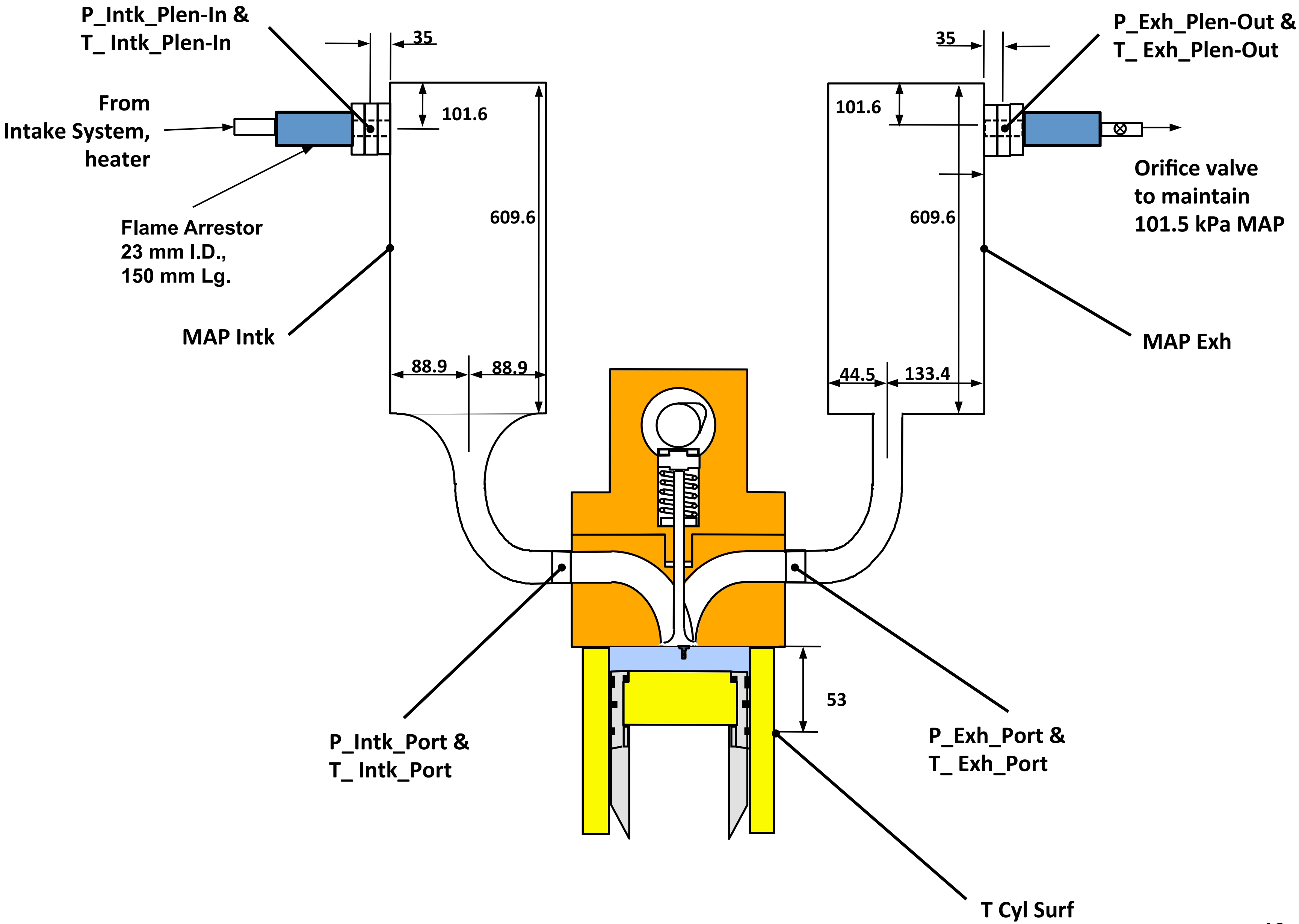




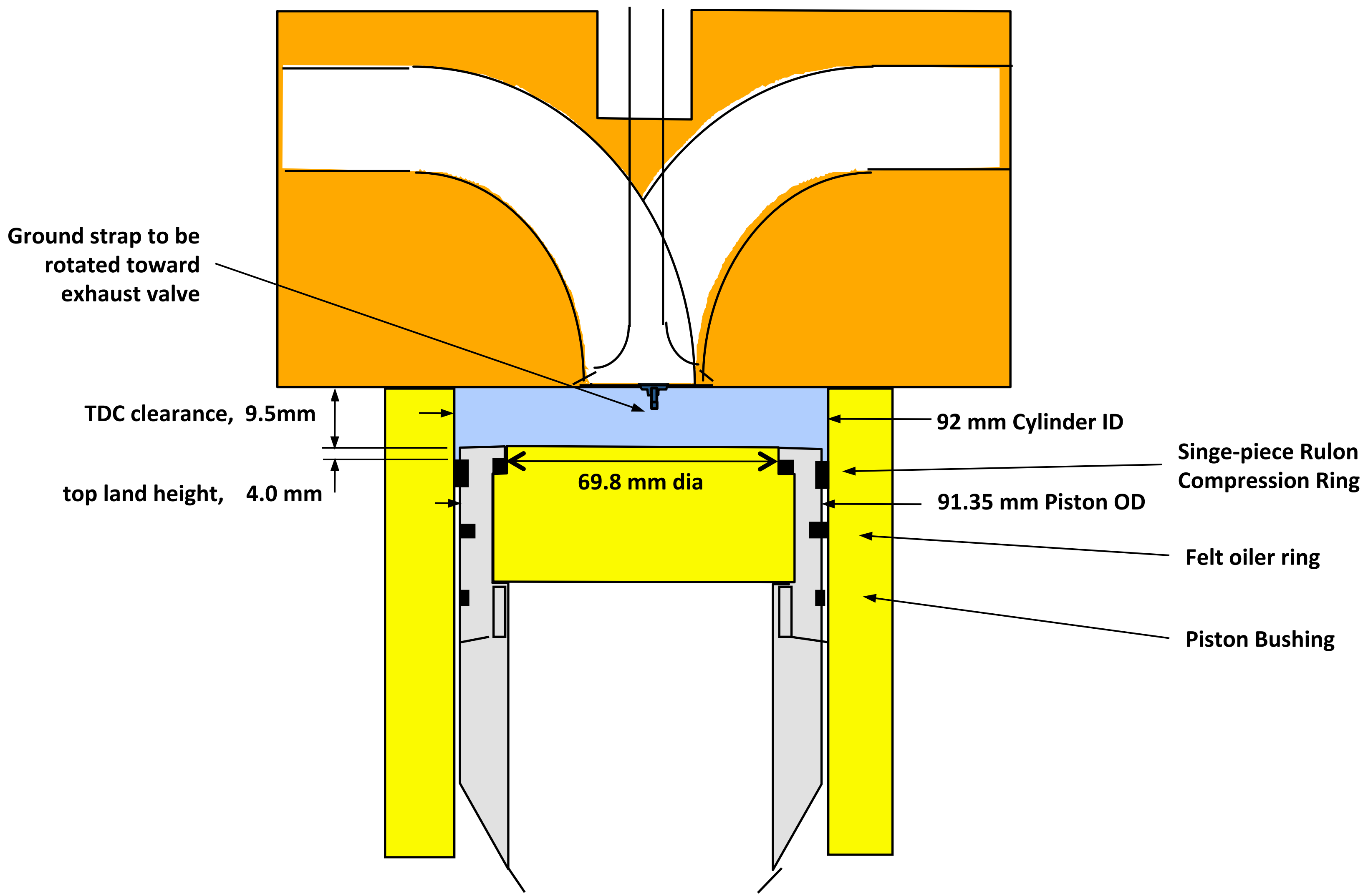


Plenum Interior Dimensions & Measurement Locations

Dimensions in mm

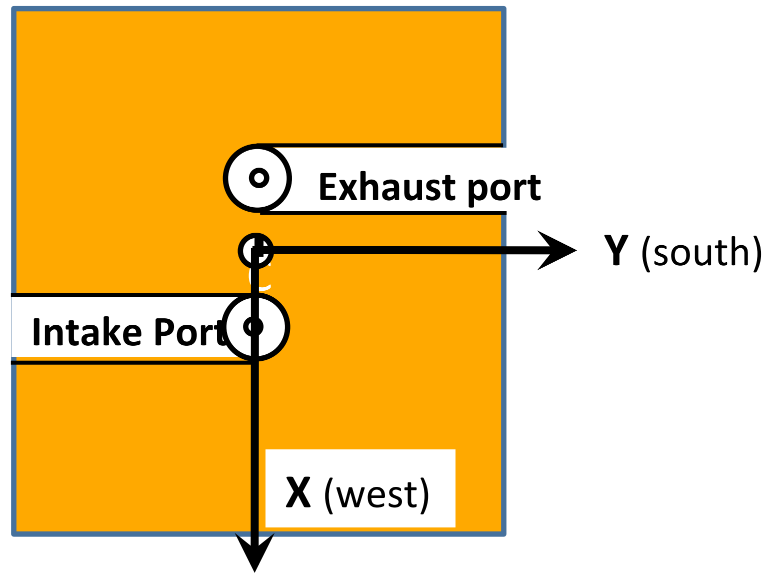


Combustion Chamber

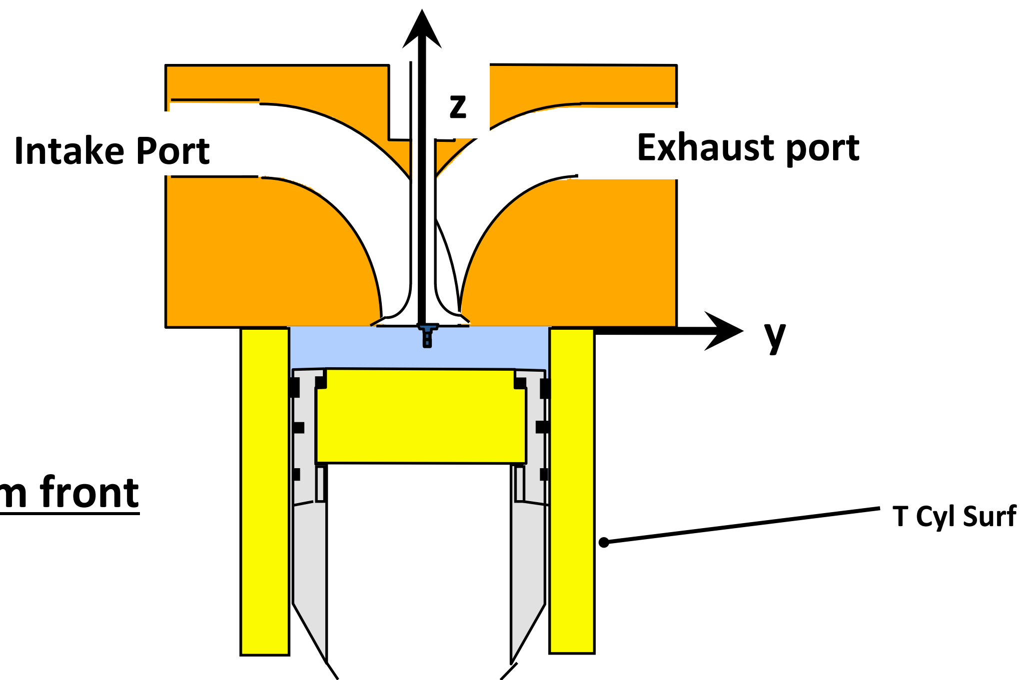


Coordinates

View from above

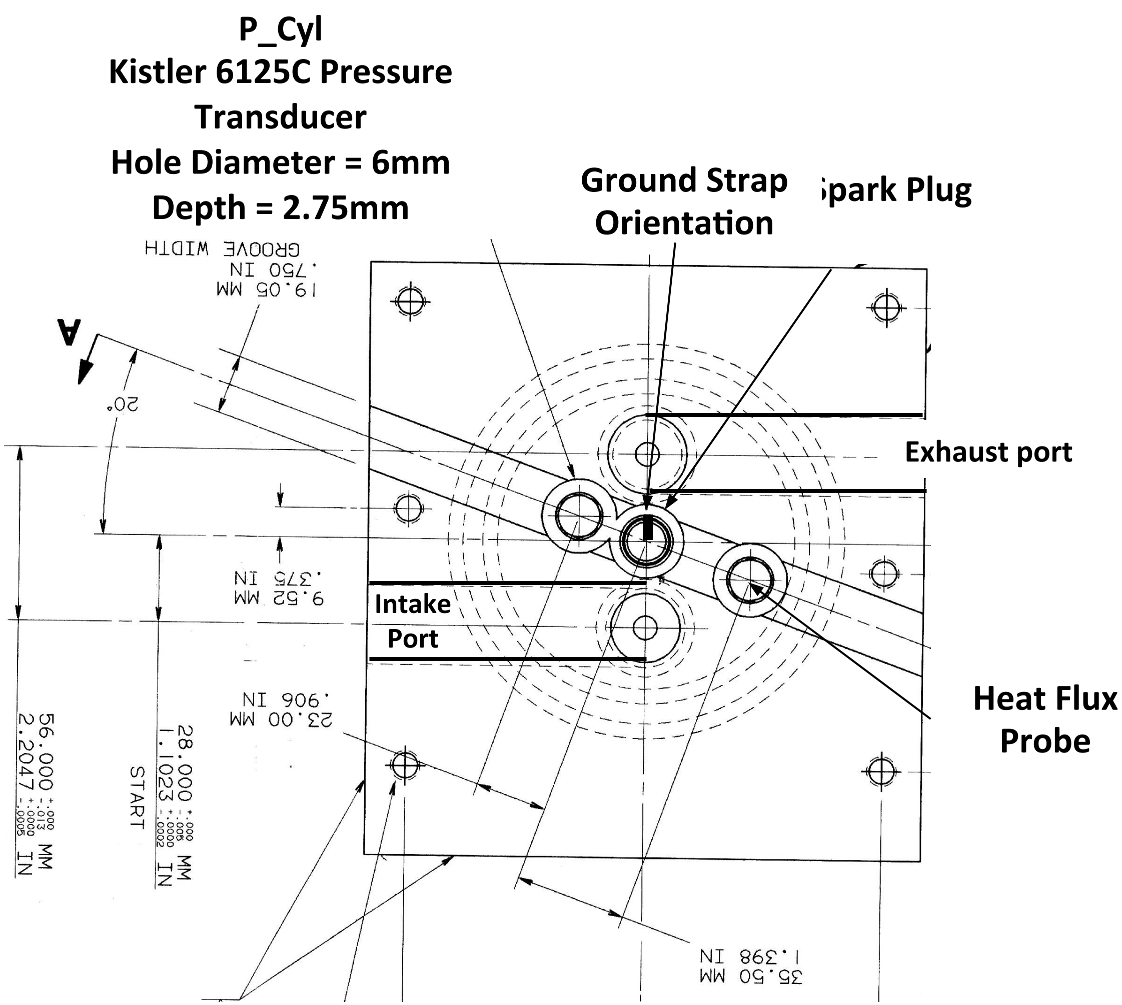


View from front

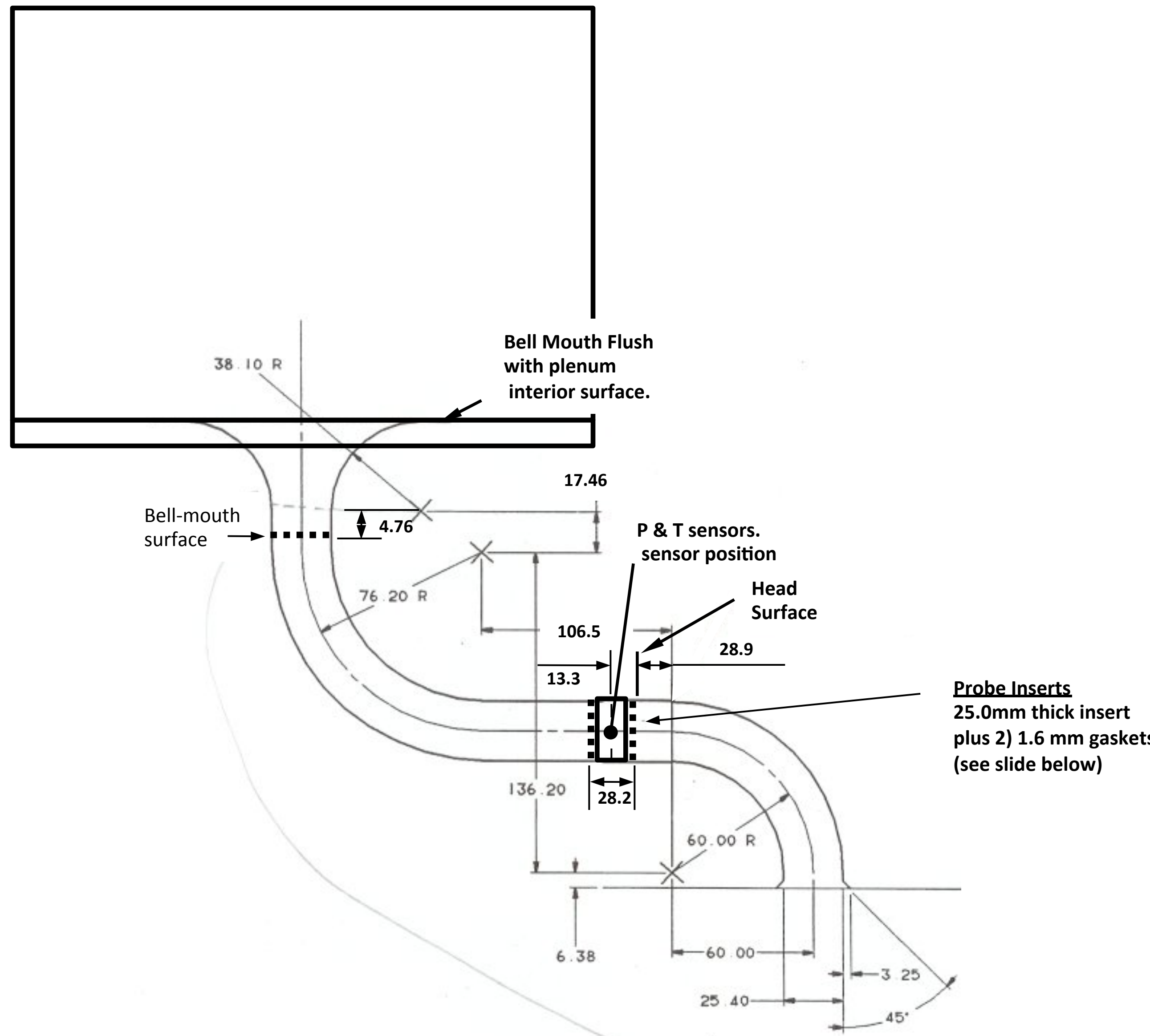


Head

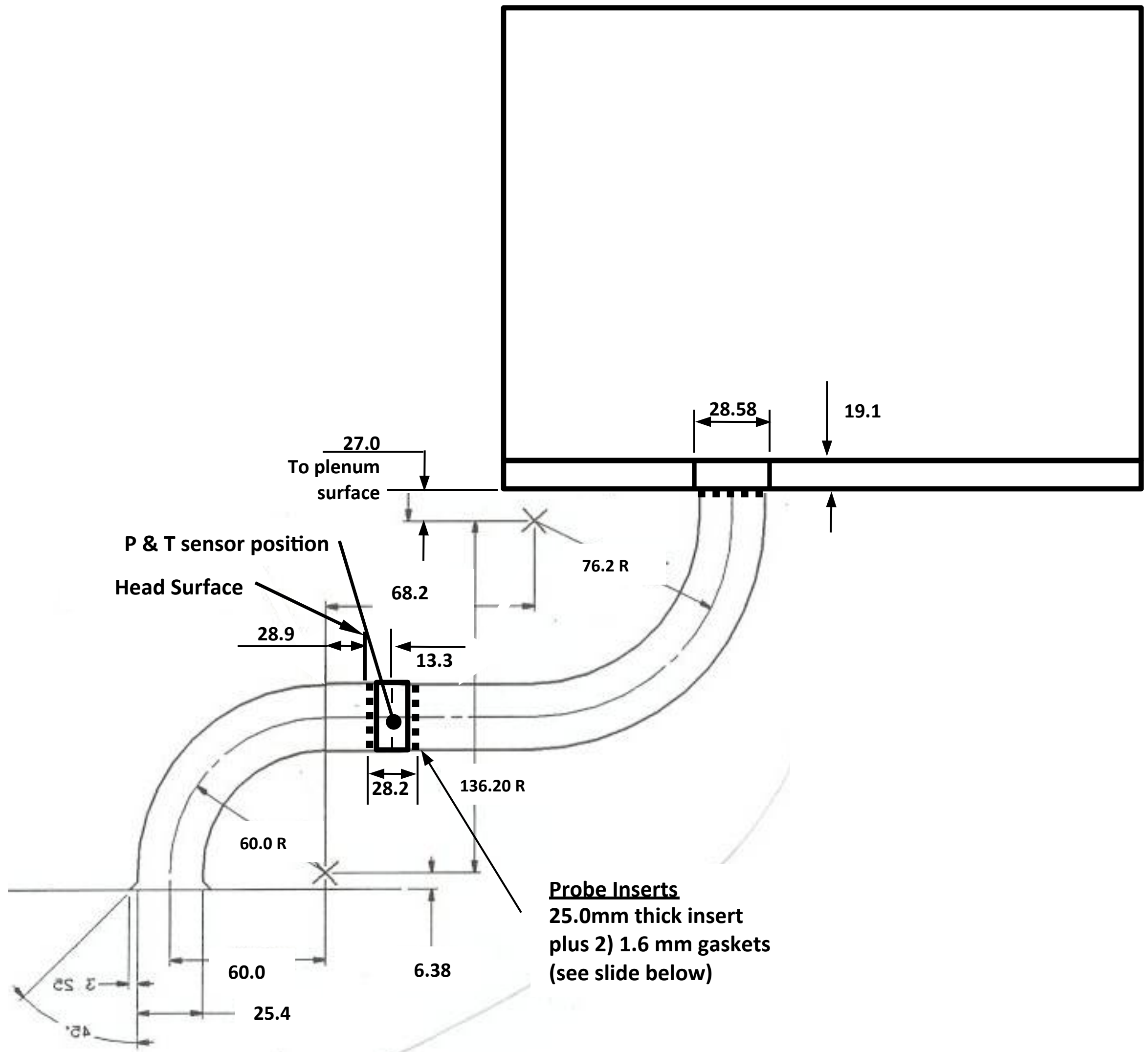
Top View



Intake Runner and Port



Exhaust Runner and Port

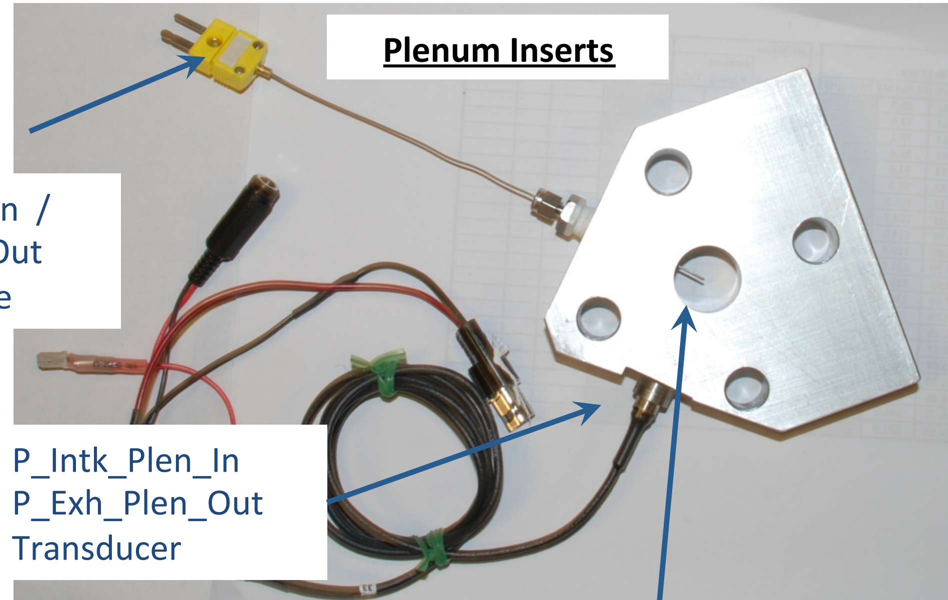


Intake and Exhaust Probe Inserts

For pressure transducers and thermocouples

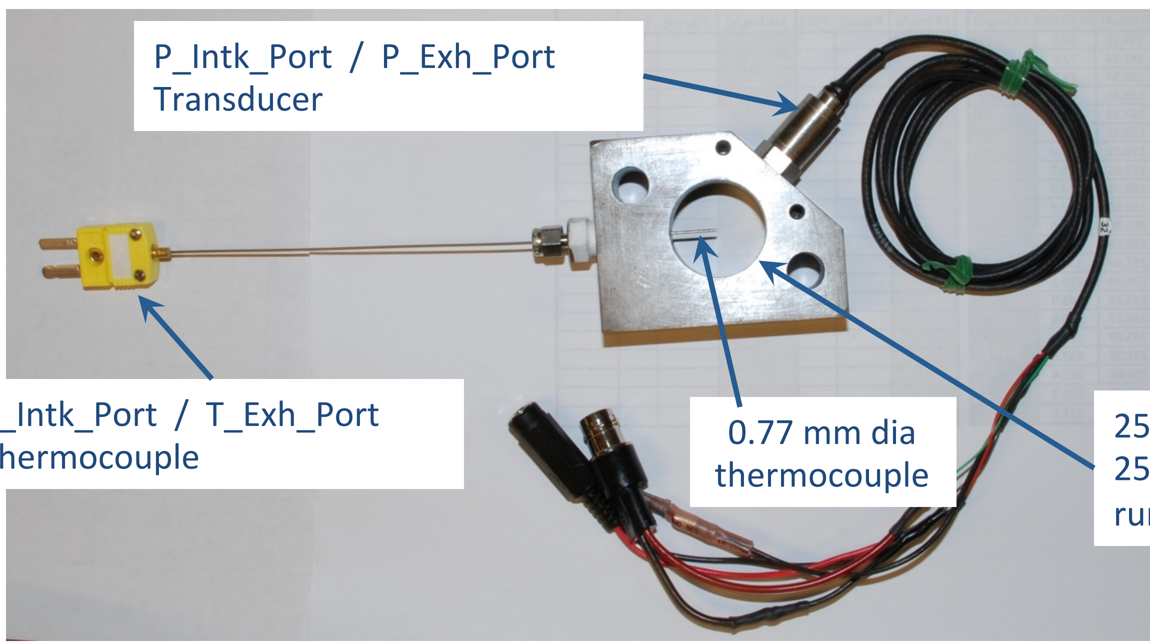
TCC-II Kulite Transducers shown in photo

Replaced by Kistler transducers in TCC-III



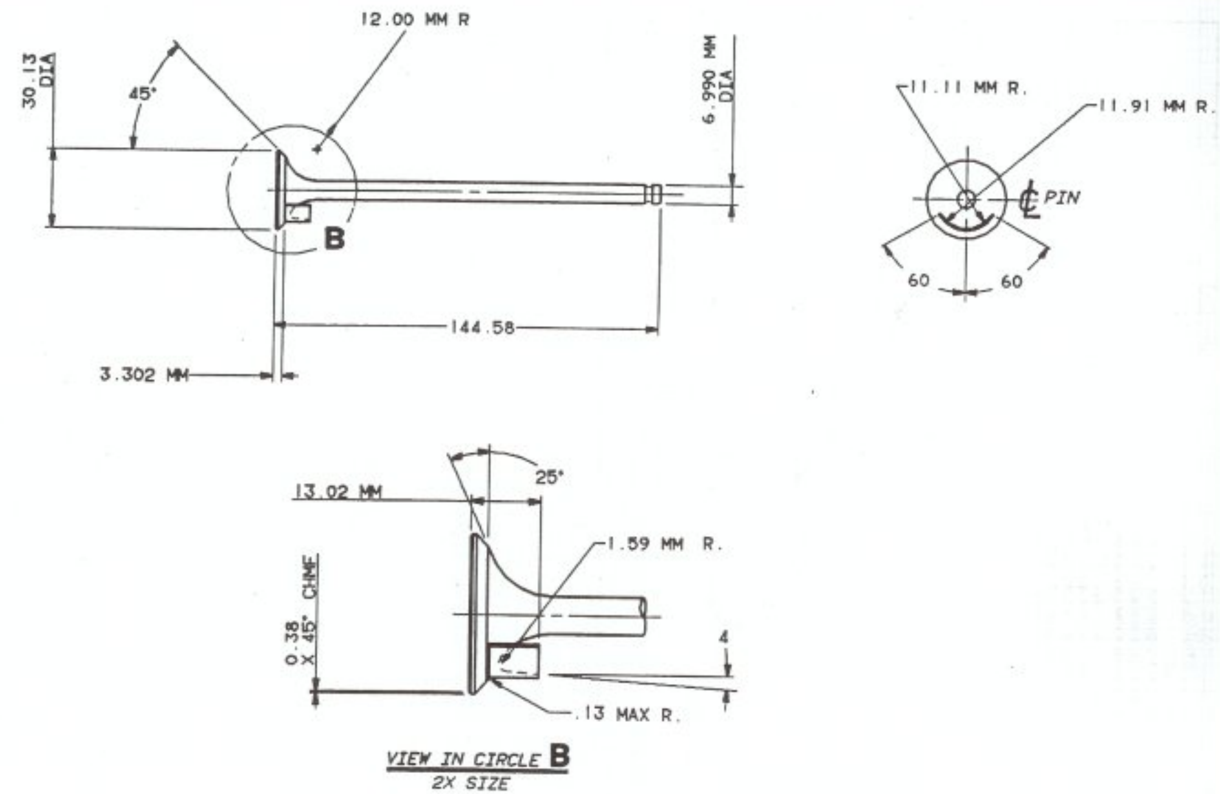
25.4 mm thick insert
19.1 mm holes to match plenum outlet-pipe I.D.

Runner/port Inserts



25.4 mm thick insert
25.4 mm holes to match runner and port diameters.

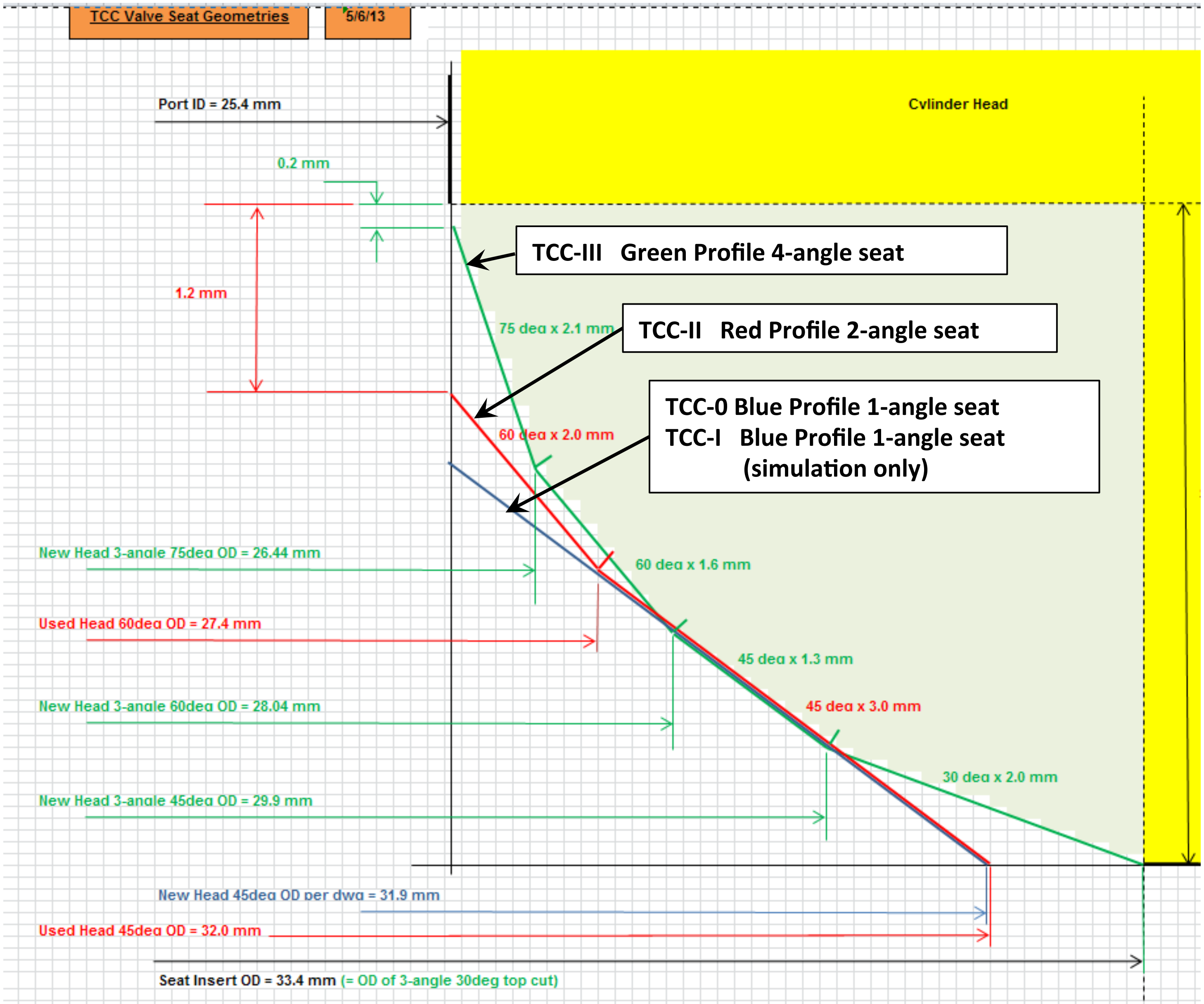
TCC-0 single-angle Valves



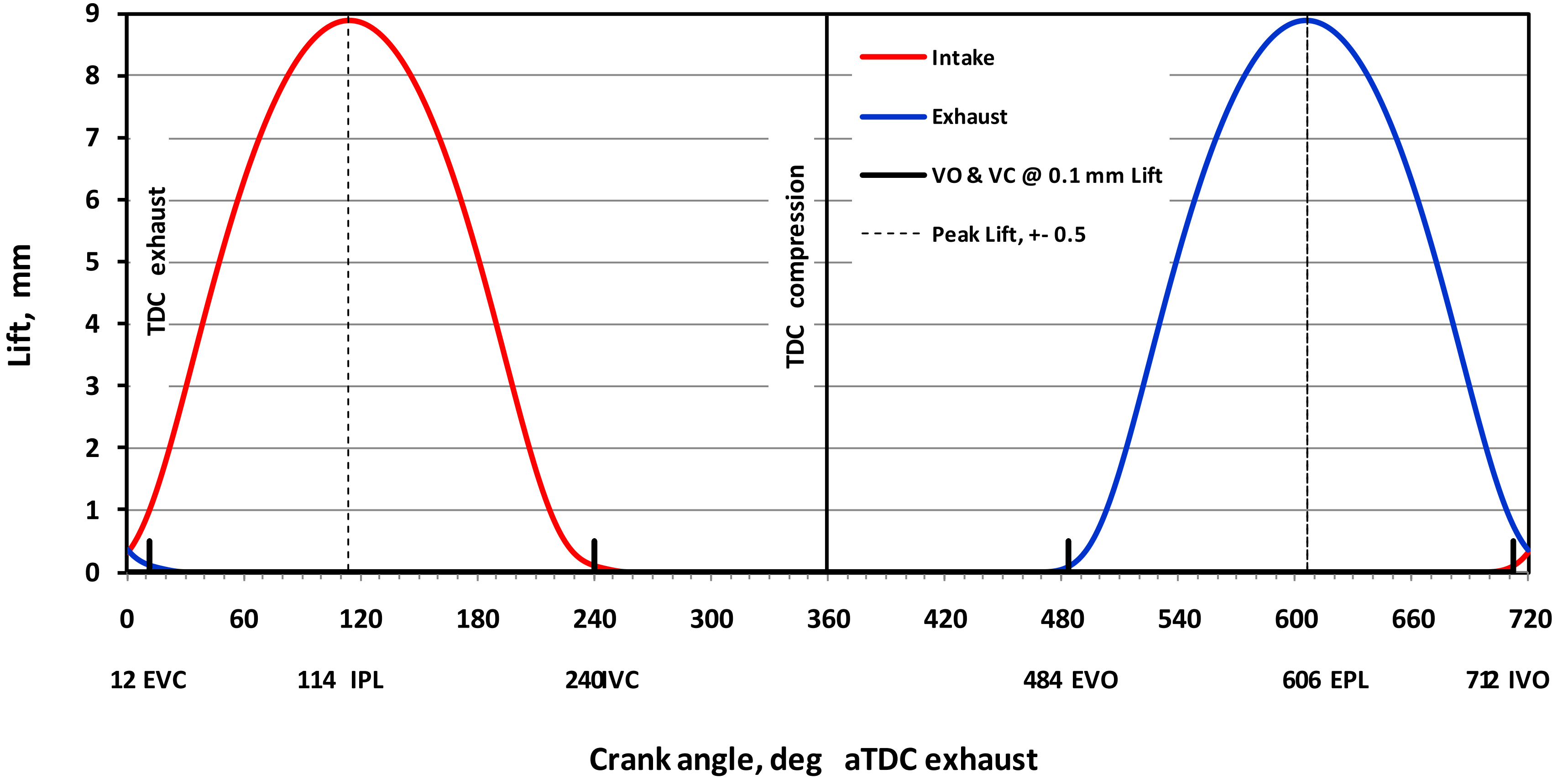
Unshrouded intake valve and exhaust valve are the same but with no shroud.

Figure 3 Details of the TCC-engine shrouded intake valve.

TCC Valve Seat Anthology



Nominal Cam Timing



Cam Profile

Original used for grinding cams

F-252

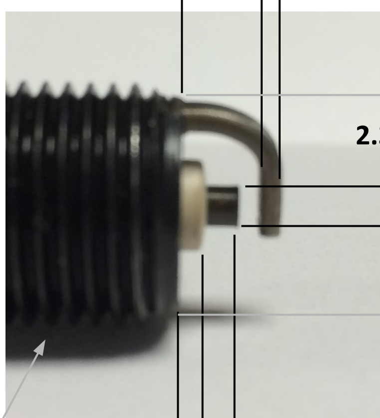
CAM CONTOUR DATA

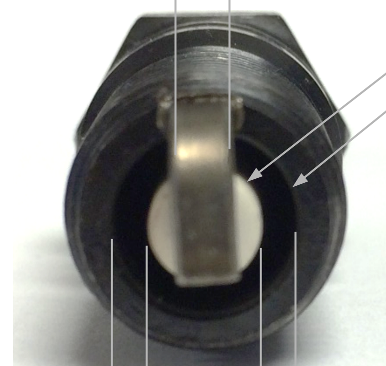
ANGLE	OPENING	CLOSING	ANGLE	OPENING	CLOSING	
0	8.8900	8.8900	40	3.4591	3.4647	
1	8.8864	8.8864	41	3.2182	3.2246	
2	8.8758	8.8758	42	2.9780	2.9853	
3	8.8580	8.8580	43	2.7397	2.7481	
4	8.8331	8.8331	44	2.5045	2.5141	
5	8.8011	8.8011	45	2.2736	2.2846	
6	8.7620	8.7620	46	2.0485	2.0610	
7	8.7158	8.7158	47	1.8306	1.8448	
8	8.6625	8.6625	48	1.6212	1.6374	
9	8.6021	8.6021	49	1.4218	1.4402	
10	8.5346	8.5346	50	1.2337	1.2547	
11	8.4600	8.4600	51	1.0582	1.0820	
12	8.3783	8.3783	52	0.8963	0.9233	
13	8.2896	8.2896	53	0.7490	0.7793	
14	8.1939	8.1939	54	0.6167	0.6508	
15	8.0911	8.0911	55	0.4997	0.5379	
16	7.9813	7.9813	56	0.3979	0.4404	
17	7.8646	7.8646	57	0.3109	0.3578	TDC
18	7.7409	7.7409	58	0.2379	0.2892	
19	7.6102	7.6102	59	0.1776	0.2331	
20	7.4727	7.4728	60	0.1290	0.1882	
21	7.3284	7.3286	61	0.0904	0.1525	open
22	7.1772	7.1775	62	0.0605	0.1242	
23	7.0194	7.0197	63	0.0381	0.1016	closed
24	6.8548	6.8552	64	0.0220	0.0830	
25	6.6837	6.6842	65	0.0113	0.0669	
26	6.5061	6.5067	66	0.0047	0.0522	
27	6.3222	6.3229	67	0.0014	0.0384	
28	6.1320	6.1329	68	0.0002	0.0259	
29	5.9357	5.9367	69	0.0000	0.0153	
30	5.7335	5.7347	70		0.0074	
31	5.5256	5.5271	71		0.0025	
32	5.3123	5.3140	72		0.0006	
33	5.0939	5.0959	73		0.0000	
34	4.8707	4.8730				
35	4.6431	4.6458				
36	4.4116	4.4148				
37	4.1768	4.1805				
38	3.9393	3.9435				
39	3.6998	3.7046				

Spark Plug

AC Delco R44LTS

Dimensions in mm

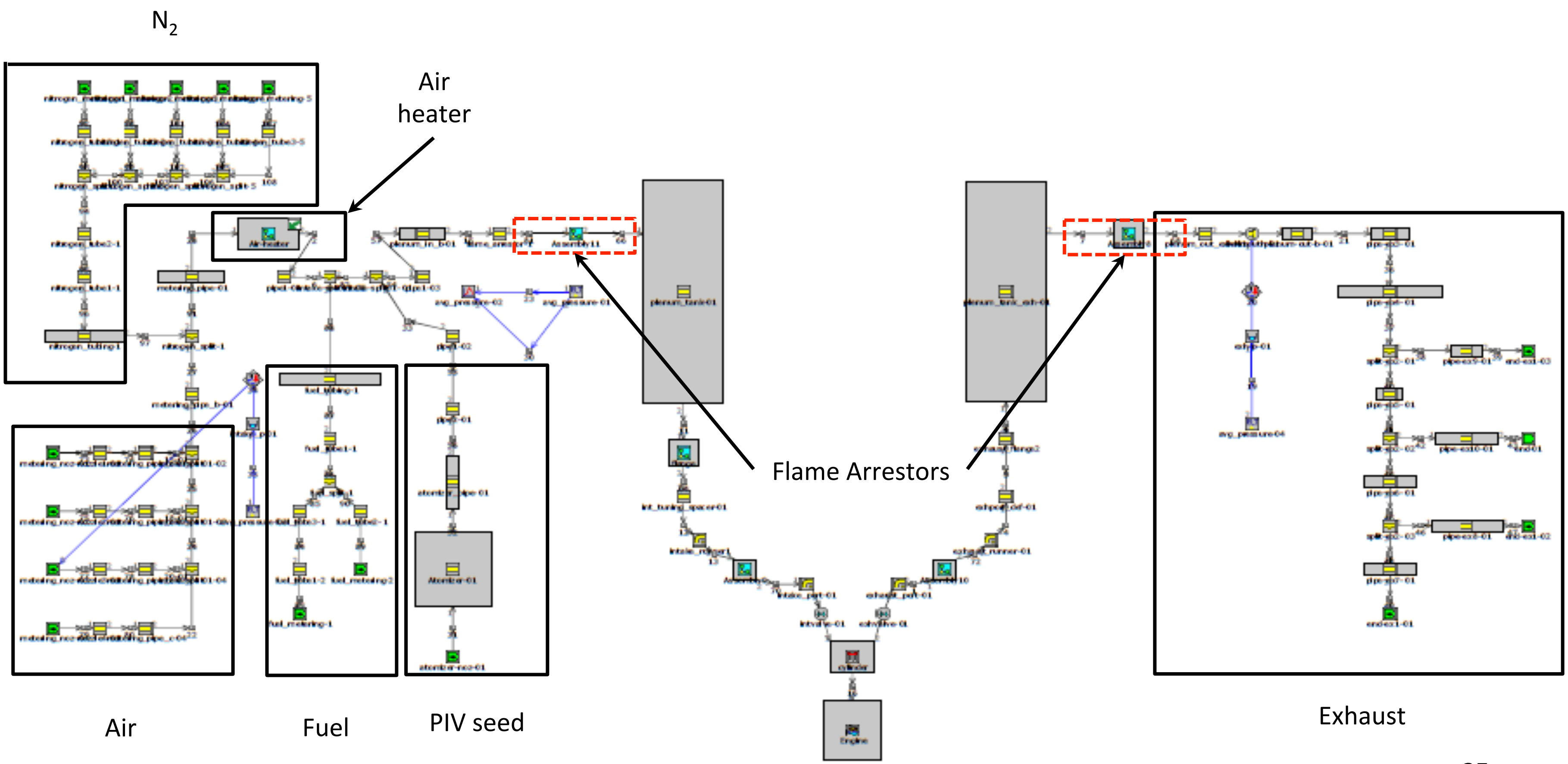




TCC-III GT-Power Summary of Intake and Exhaust Systems

The following slides provides detailed information on the intake and exhaust system geometries. This was used to create the GTPower 1-D model .gtm and .gdx files (located in the TCC-III_Geometry directory shown in Slide 6). In addition, the geometry slides define the nomenclature and locations of the pressure transducers and thermocouples cataloged in the Pressure Data Files.

Scanned figures of original printed material are used to avoid transposition errors. The Deep Blue Data TCC-III Collection README file contains errata, which are updated as they become available.



TCC-II Engine & Systems

Air Heater

Air Line
Heater to
Intk_Plen_In

Exh_Plen_Out
Probe Inserts
(TCC-III flame arrestor
not shown)

Intk_Plen_In
Probe Inserts
(TCC-III flame arrestor
not shown)

Exhaust back-pressure valve

Map_Intk Sensor

MAP_Intk tap

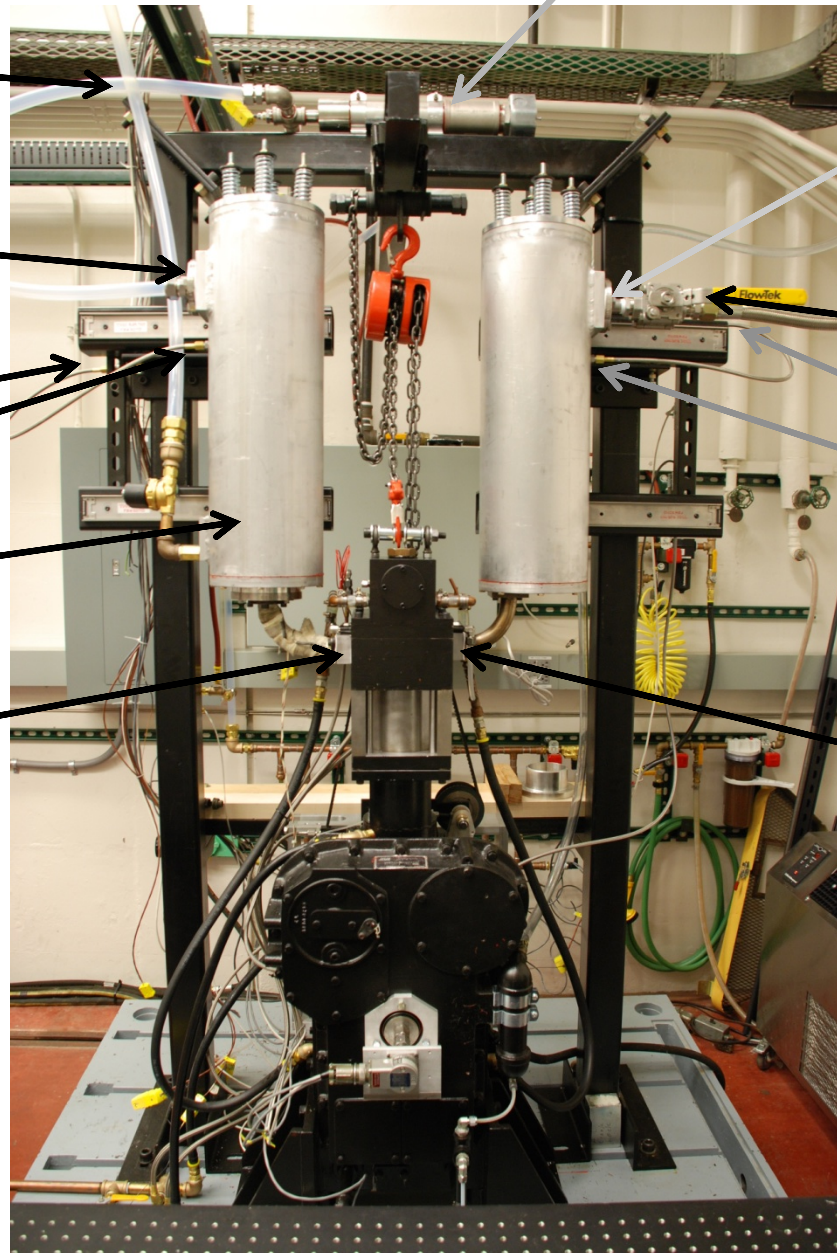
Map_Exh Sensor

MAP_Intk tap

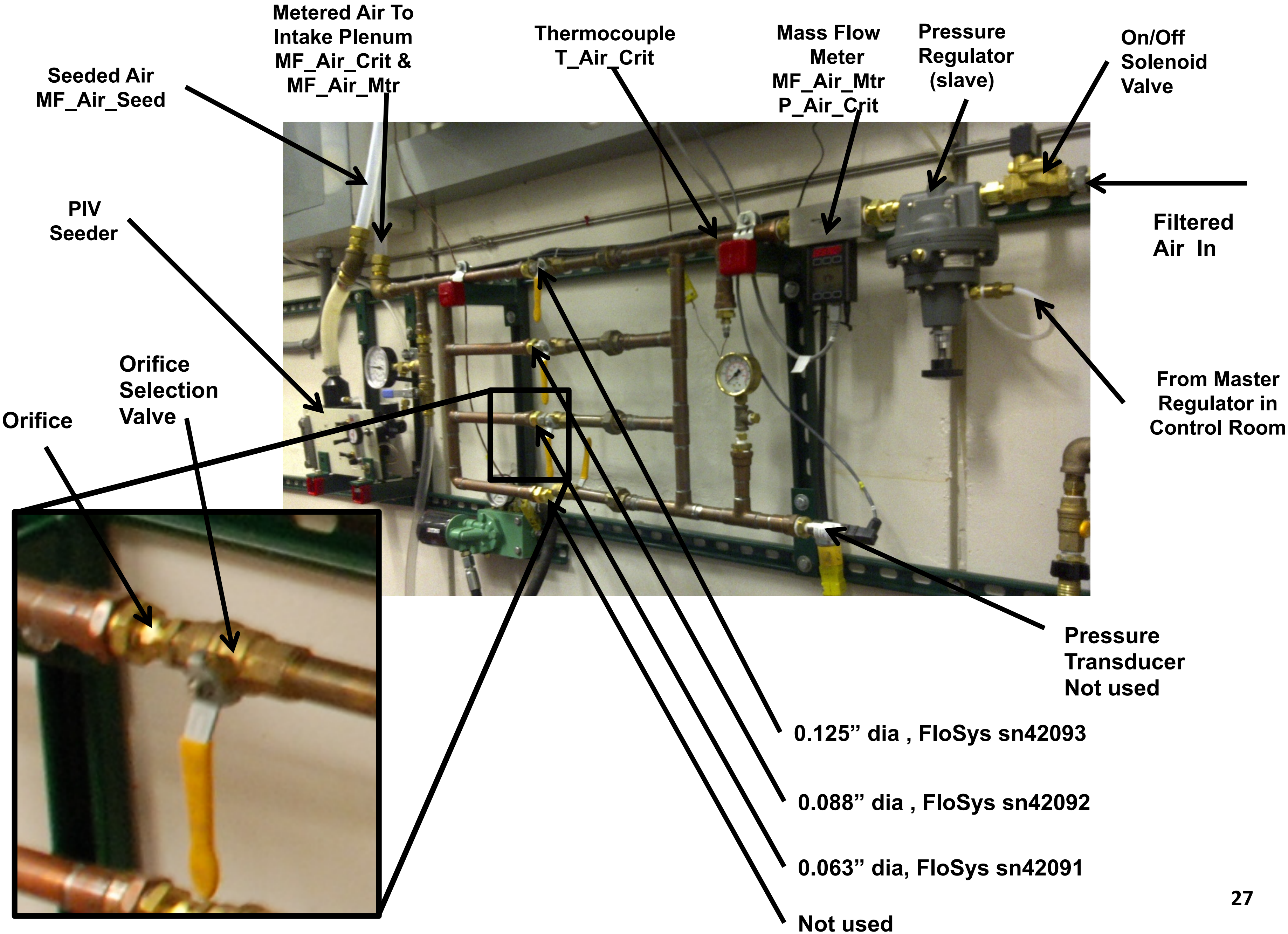
Heaters &
Insulation
not shown

Intk_Port
Probe Insert

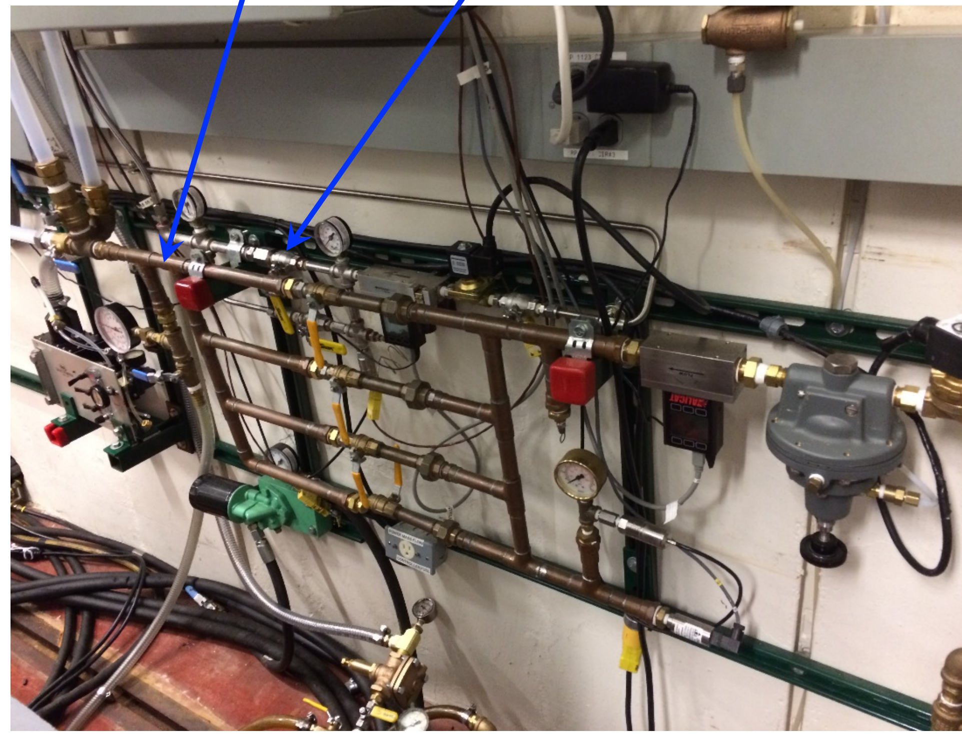
Exh_Port
Probe Insert



TCC-II Critical Flow Metering System, Air Only



TCC-III Critical Flow Fuel Metering Systems, Air & Fuel

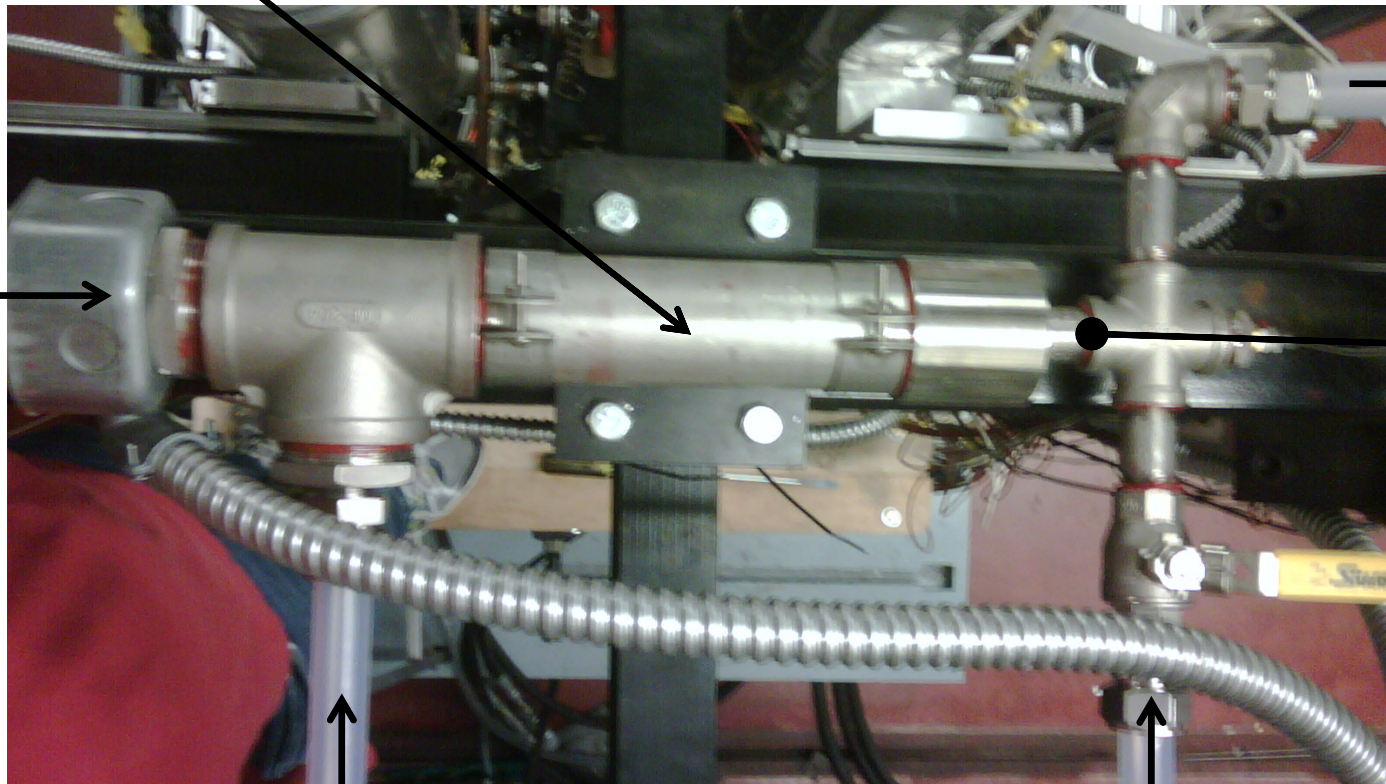


Air Heater

5.1 cm I.D., 34 cm Lg.

Insulation
not shown

Immersion
Heater

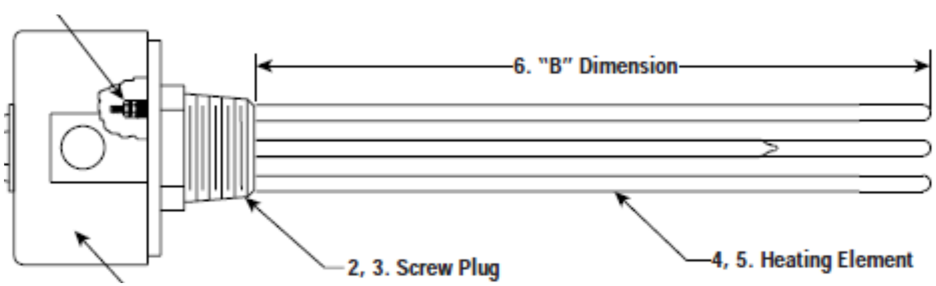


To Plenum Inlet
MF_Air_Tot

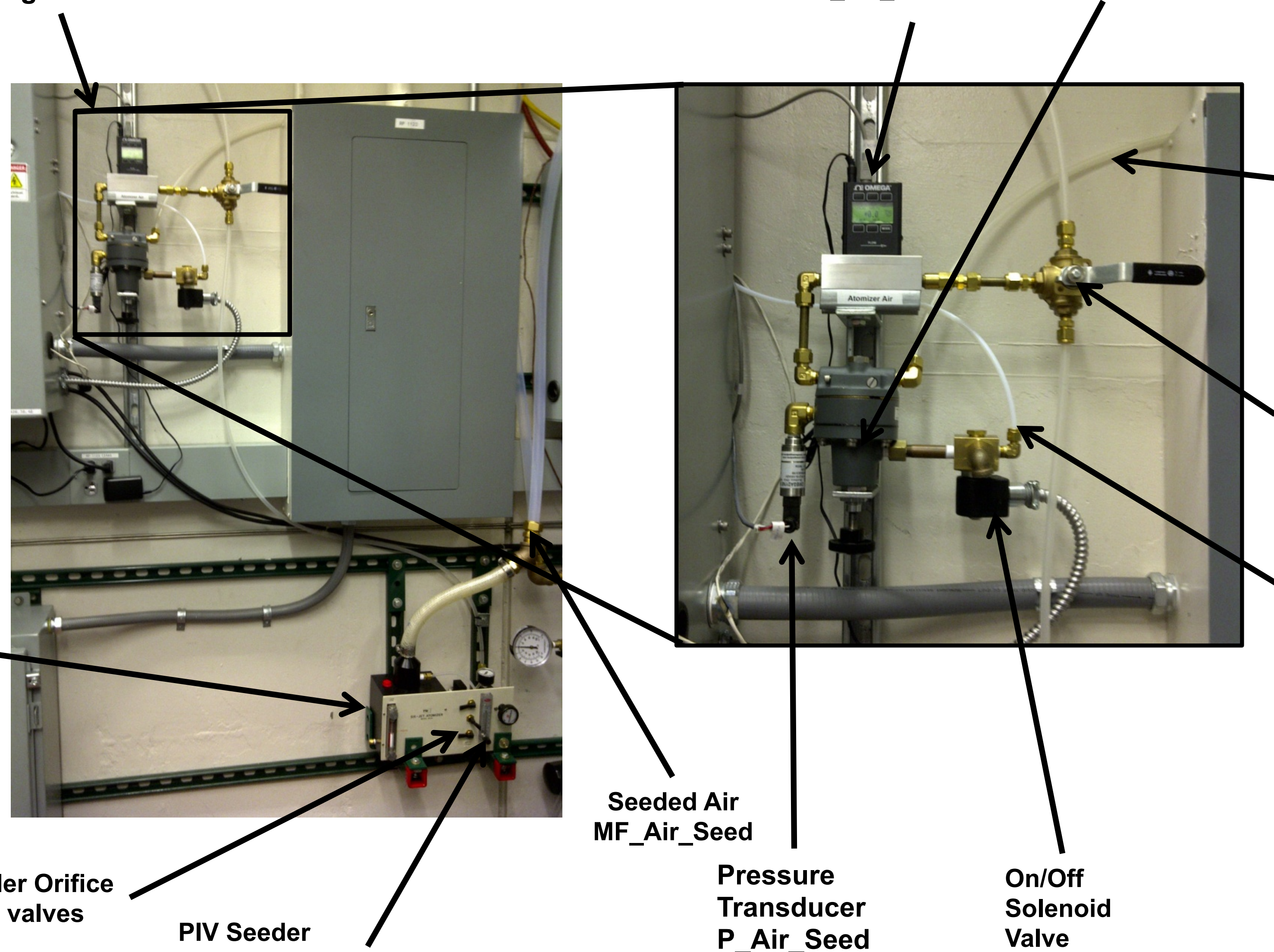
T_Air_Heater

Metered Air From
Critical Flow Metering System
MF_Air_Crit, T≅ ambient

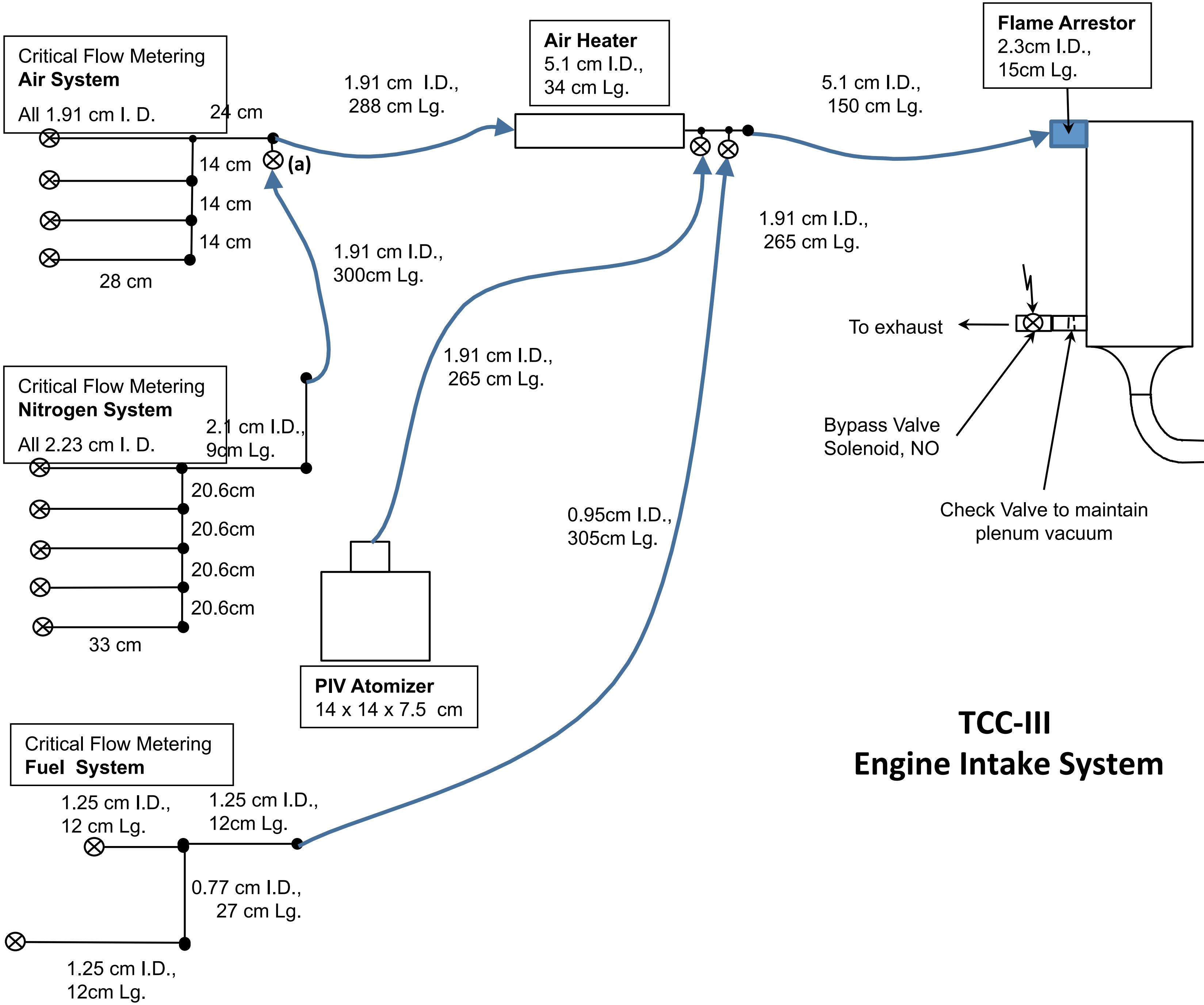
Metered Air From
PIV Atomizer
MF_Air_Seed, T≅ ambient



Seeder Flow-Metering System,



TCC-III Engine Intake System



TCC-III Engine Exhaust System